The Landscape Agroforestry Modeling for Sufficiency Economy in term of Environmental Factor in Huai Raeng-Klong Peed Sub-watershed, Trat Province of Thailand

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Abstract: This research considered the sufficiency economy theory in term of environmental factor to conduct for establishment land use modeling on landscape scale or landscape agroforestry. Land suitability method is procedure to encounter the land suitability, and integrated it with analysis hierarchy process (AHP) to evaluate criteria and indicators. The specific objectives of this research are to study key performance to indicate the agroforestry under sufficiency economy in term of environmental factor, to develop the model achieve to agroforestry under sufficiency economy in term of environmental factor and to establish landscape agroforestry map in study area through to sufficiency economy in term of environmental factor.

Indices in the modeling were investigated weighted by literature reviews and expert scoring. The agroforestry indices (AFI) are shown as follows,

AFI_{ENV}= [[10((0.1R_{OM})+(0.69R_{ERO})+(0.21R_{SPD}))]]/10 where AFI is agroforestry indices in term of environmental factor, R_{OM} is ranking of organic matter, R_{ERO} is ranking of soil erosion and R_{SPD} is ranking of species diversity.

The landscape agroforestry indices (LAFI) are shown as follows,

$LAFI_{ENV}$=[[10((0.09R_{SOT})+(0.61R_{SLP})+(0.30R_{DTW}))]+[7((0.83R_{WCL})+(0.17R_{CON}))]]/17 where LAFI is landscape agroforestry indices in term of environmental factor, R_{SOT} is ranking of soil types, R_{SLP} is ranking of slope, R_{DTW} is ranking of distance to water, R_{WCL} is ranking of watershed classes and R_{CON} is ranking of conservation area.

Site observation data were taken into the agroforestry index equation. The results were land use types which is appropriate for sufficiency economy in term of environmental factor. The high level was residential and mixed fruit, the medium level were Para rubber /fruit orchard, Para rubber plantation, Mixes fruit orchard and Eagle Wood /Para rubber and the low level was oil palm.

The secondary data from institutions were rank score. They were taken into the landscape agroforestry index equation. The results were land which is suitability for land use type under sufficiency

economy in term of environmental factor. The comparison between the landscape agroforestry index class map ($LAFIC_{ENV}$ map) of unremarkable or follow the equation and the map which is immovable forest. The highest area in unremarkable condition was high suitable area as 233.99 km^2 but the highest area in immovable condition was high suitable area as 172.47 km^2. The both conditions still have the highest and high area for cultivation more than half of total area. The immovable condition map which emphasize on ecosystem have 5 levels. The highest suitability area has 113.61 km^2, high suitability area has 172.47 km^2, medium suitability area has 3.02 km^2, low suitability has 0.01 km^2 and the lowest suitability area has 158.10 km^2.

Keyword: Agroforestry, Landscape Agroforestry, Sufficiency Economy, Modeling.

INTRODUCTION

Deforestation of global forest area has been decreasing especially in tropical forest, mainly tropical forests conversion is agriculture (Food and Agriculture Organization of the United Nations [FAO], 2010). Agricultural expansion is widely and large scale. This result is the loss of multiple functions and decrease of land productivity due to soil erosion, flood, drought and some lands become eventually abandoned

In the past, Thailand was well known for its rich forest resources. In 1961, forest still occupied more than haft of the total land area. However, the forest covers in 2009 was only 33.56% of the land area. Mainly of deforestation in Thailand is agriculture that widely and large scale. Landscape agroforestry is mosaic of different land use types and large-scale, it is spatial interaction as several systems of a farm. Landscape agroforestry where is ecological processes are best understood. Particularly, better explain environmental phenomena, that the tool for the policy maker to natural resource management. Thereby, the study in term of large scale is important to understand in term of ecosystem.

Deforestation can be reduced in several ways. One way is simply new plantation on deforested area and agroforestry. Agroforestry is basically a land-use, where woody perennials are deliberately used with agricultural crops or animal on the same land management unit. Agroforestry is a dynamic ecological based management system to sustain production for social, economic and environment (The International Centre for Research in Agroforestry [ICRAF], 1993). Especially the landscape agroforestry is a mosaic of different land-use types where ecological processes are best understood. Moreover the solution of deforestation is the policy, National Development Plans have applied sufficiency economy (SE) as the framework. Sufficiency economy is a philosophy by His Majesty the King. This policy for the country's development aimed to achieve well-balanced and sustainable growth. These are two solutions, there are landscape agroforestry and sufficiency economy can be solved degraded forest land use.

The importance tool for policy maker is modeling. Modeling can provide understanding, visualization and important communication tools. This research is developing as a model for land suitability mapping. The model considers the environment, economic and social to achieve to find the land use under the sufficiency economy theory. The model is tool, which can examine the impact of land use that arises from land use planning by a government and land use change without the control. Therefore, this is the useful tool for land use planning and can detect quick damage to manage with urgently problems.

OBJECTIVES

1. To study key performance to indicate the agroforestry under sufficiency economy.
2. To develop the model achieve to agroforestry under sufficiency economy in term of environmental factor.
3. To establish landscape agroforestry map in study area through to sufficiency economy in term of environmental factor.

MATERIALS AND METHODS

Materials

1. Topography map scale 1: 50,000 of Royal Thai Survey Department sheet number 5433 I, 5433 II and 5433 III, 1997 year
2. Land use map of the Land Development Department, 2010 year
3. Soil types map scale 1:50,000 of Land Development Department, 2002 year
4. Watershed classes map scale 1:50,000 of Natural Resources and Environmental Management Division, 2001 year
5. National park map scale 1:50,000 of Royal Forestry Department, 2004 year
6. Program Arc GIS version 9.3 and Microsoft office 2007
7. Computer notebook
8. Sample collection of soil; spatula, or knife and small paper bags.

Methods

1. Site selection

The Huai Raeng-Klong Peed sub-watershed was selected for the study site. This sub-watershed is a part of Trat province, Eastern Thailand (Figure 1). The source of the sub-watershed is the north-south longitudinal mountainous range called Banthat's Mount separating border of Cambodia and Thailand. It located in the east coast gulf sub-watershed and consists of 10 sub-watersheds. The area and perimeter is 445.37 km^2. This sub-watershed has several of land use and most land use based on woody perennial that it is called agroforestry.

Land use in 2010 in the study area was classified into 22 types. Natural forest/forest plantation was the major land use in the sub-watershed (34.185%). Rubber plantations were an important cultivated land area (26.18%). Grass/abandoned land, mixed fruit orchards, rubber and pine apple represented 9.50, 7.77 and 7.28 % respectively. The land use types were shown in Figure 2.

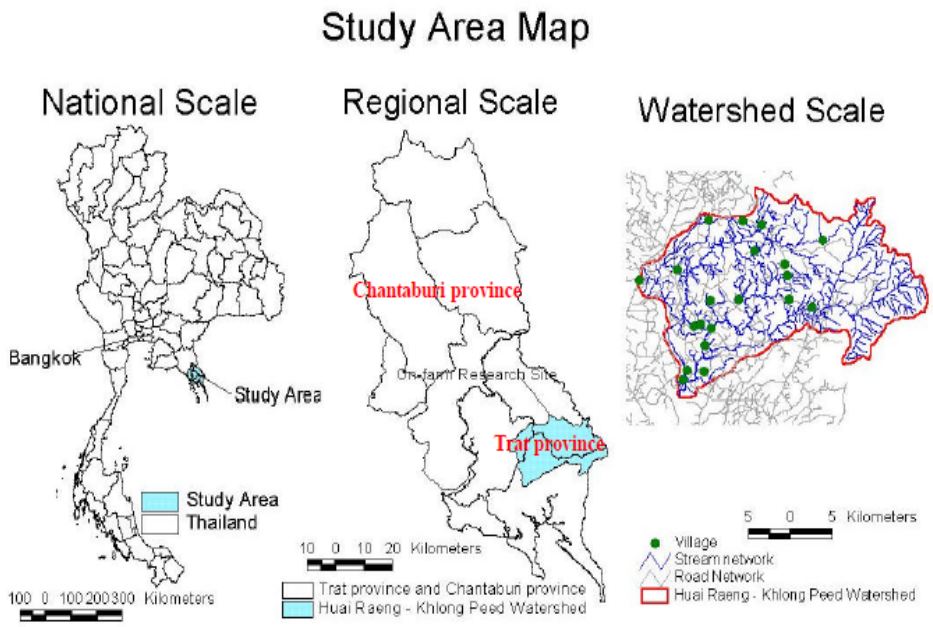


Figure 1 Study area in Huai Raeng-Klong Peed sub sub-watershed, Eastern Thailand

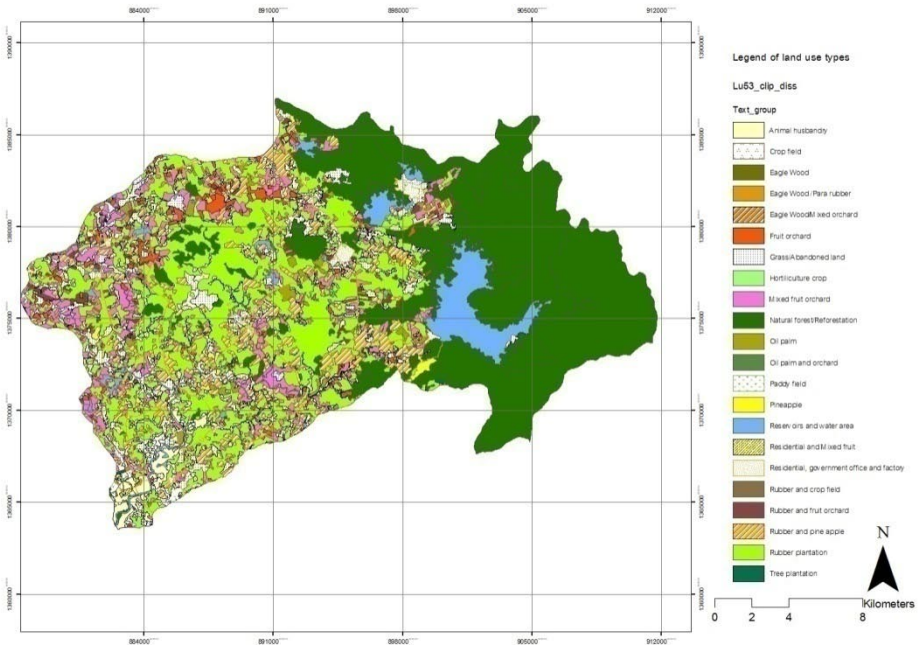


Figure 2 Land use types of Huai Raeng-Klong Peed sub-watershed in 2010

2. Methodology

The goal of this research is landscape agroforestry under sufficiency economy (SE). There are two investigate as following;

1) Agroforestry classes; land use types and classification, which is suitability to sufficiency economy.

2) Landscape agroforestry classes; landscape characteristics, which is qualification for each of land use types.

Land suitability was the main process of this research. A multi criteria decision making (MCDM) has chosen to approach for weighting criteria. This was formulated using by criteria weight as analytic hierarchy process (AHP) weighting method. Combining the weights and the indicator maps generates land use maps, which is using compromise GIS based on AHP. The land use map is a potential land use area based on sufficiency economy.

2.1 Defining a goal of landscape agroforestry under sufficiency economy.

Defining a goal of landscape agroforestry under sufficiency economy, it studied in interpretation each level of the government institutions. The results all of level studied were applied in the two objectives as following.

2.1.1 Agroforestry indices

The agroforestry indices were studied in the concept of sufficiency economy and the land quality concept. The land quality concept studied in the land degradation (LD). It was studied by FAO in the land degradation assessment in dry lands project (LADA) during the period 2006-2010 (FAO, 2011).

2.1.2 Landscape agroforestry indices

The landscape agroforestry indices were studied in relevant researches in term of land suitability and land quality.

2.2 Estimate weighting of factors, criteria and indicators

Each factor estimates by experts on questionnaire. Ratio method was used estimate weighting. The pairwise comparison method was used estimate weighting, in the context of the AHP.

The criteria considered of the experts who is related in agroforestry aspect, agriculture aspect and the government institution in term of land use planning policy as following.

1) Agroforestry aspect

This aspect studied in the members of The Thai network on agroforestry education (ThaiNAFE) and the lecture teaches the subjects of agroforestry related.

2) Agriculture aspect

This aspect studied in the lecturer teaches in faculty of agriculture in the university who has expert in agricultural land use management or has research related in agricultural land use management. Besides to study in the lecturer in faculty of economic in the university who teaches in agricultural economic field and interested in sufficiency economy.

3) The government intuitions related in land use planning policy

There were three intuitions related as Royal Forestry Department, Land Development

Department and Department of Public Works and Town & Country Planning.

The mailed questionnaire was a tool to estimate weighting from the experts. They were sent 62 series, and the others were sent by researcher 18 series. The questionnaire proportion in each of aspects was showed in Table 1.

2.3 Formulation of equation and classification

Establishing equation of objective create linear equation, which are combination each of indicator value of criteria consist of agroforestry index and suitable index for landscape agroforestry, equation as below.

$$S = \frac{\sum_{i=1}^{n} W_i.R_i}{\sum_{i=1}^{n} W_i} \quad \text{.....(1)}$$

Where S is sum of overall cumulative suitability

W_i is weight of each factors

R_i is score ranking of each factors

i is a factor number 1 to n.

2.4 Agroforestry classes

Agroforestry classes are classification of land use which is suitability to sufficiency economy. The classification is divided from above equation (1). The value of indicator in equation is established in a plot of the study area in each of land use. The detail of each step is as following below**.**

2.4.1 Identification land use types Identification and grouping land use types map in 2010 of land development department by geographical information system (GIS) application software. Criteria selections of the land use were; choose the land use types by ranking as a lot of land use area and choose the land use types base on woody perennial or agroforestry. The land use types were chosen as show in Table 2**.**

2.4.2 Analysis of land use through to sufficiency economy

The completely randomized design (CRD) has been chosen to experimental design. The land use types were chosen, they were sorted with slope class and soil series. There are two groups, land use types on slope class 0-6% and 6-25%. The treatment is types of land use were chosen in Table 2. The sample plot design is two sample plots in each of land use types, there are 12 sample plot**s.**

2.4.3 Analysis of land suitability under sufficiency economy

Geography information system is a tool to establish landscape agroforestry index class map.

Table 1 The questionnaire proportion in each of aspects.

Aspects	Questionnaires	%
Agroforestry aspect	22	27.5
Agriculture and sufficiency economy aspect	38	47.5
The government intuitions related aspect	20	25
Total	80	100

Table 2 The land use types were chosen to study

No.	Land use types
1	Para rubber plantation
2	Mixed fruits orchard
3	Oil palm
4	Para rubber and fruit orchard
5	Residential and Mixed fruit
6	Eagle Wood /Para rubber

Table 3 The methodological study in each of indicators

Indicators	Methodology of each indicator
Soil properties	Organic matter (OM); Sampling soil samples were randomly collected 3 point in 40 x 40 meters plot size, each plots have a second level soil depth is 0-15 cm and 15-30 cm.
Soil erosion	Soil erosion in each of land use was studied in relevant research
Vegetation	Species Diversity; the index was applied to quantify the diversity of the plant species is the Shannon index (*H'*) as a measure of species abundance and richness is applied. The equation is $H' = \sum_{i=1}^{s} p_i \ln p_i$ Where, *s* equals the number of species and p_i is the relative cover of *i*th species

RESULTS AND DISCUSSION

1. Weighting value

The results of the questionnaire were returned 58 series or about 72.5% of the populations. There are three aspects consist of agroforestry aspect, agriculture and sufficiency economy aspect and the government intuitions related aspect were returned 16, 26 and 16 series or about 20, 32.5 and 20%,respectively. The results of weighting from questionnaire were calculated by AHP technique. The AHP technique is pair wise comparison method. In additional, the weighting were calculated consistency ratio (CR) that if CR is smaller than 0.10, then degree of process and the AHP method may not yield meaningful results. There were shown as follow in Table 4 and Table 5.

2. Modeling of landscape agroforestry for sufficiency economy

Then, the weighed value were taken into equation (1) as an agroforestry index equation and a landscape agroforestry index equation as follow,

$AFI = [[10[(0.1R_{OM})+(0.69R_{ERO})+(0.21R_{SPD})]]+ [8[(0.30R_{ICD})+(0.09R_{NPV})+(0.61R_{RU})]]+[10[(0.17 R_{LHS})+(0.83R_{ALU})]]]/28$.....(2)

Where AFI = Agroforestry indices

R_{OM} = ranking of organic matter

R_{ERO} = ranking of soil erosion

R_{SPD} = ranking of species diversity

R_{ICD} = ranking of income distribution

R_{NPV} = ranking of net present value

R_{RU} = ranking of resource using

R_{LHS} = ranking of land holding size

R_{ALU} = ranking of acceptation of land use

The agroforestry indices in term of environmental factor was taken only environmental factor as shown below.

$AFI_{ENV} = [[10[(0.1R_{OM})+(0.69R_{ERO})+(0.21R_{SPD})]]]/10$.....(3)

Where AFI_{ENV} = Agroforestry indices in term of environmental factor

R_{OM} = ranking of organic matter

R_{ERO} = ranking of soil erosion

R_{SPD} = ranking of species diversity

$LAFI = [[10[(0.09R_{SOT})+(0.61R_{SLP})+(0.30R_{DTW})]]+ [7[(0.83R_{WCL})+(0.17R_{CON})]]+[10R_{ACC}]]/27$.....(4)

Where LAFI = Landscape agroforestry indices

R_{SOT} = ranking of soil types

R_{SLP} = ranking of slope

R_{DTW} = ranking of distance to water

R_{WCL} = ranking of watershed classes

R_{CON} = ranking of conservation area

R_{ACC} = ranking of access to main road

The agroforestry index classes were divided into 5 levels as shown in Table 6, and it represents the lowest level to the highest level of sufficiency economy level of land use types. In the same way the landscape agroforestry index classes in Table 7 represents the lowest level to the highest level of suitable index level of landscape scale.

The agroforestry indices in term of environmental factor was taken only environmental factor as shown below,

$LAFI_{ENV} = [[10[(0.09R_{SOT})+(0.61R_{SLP})+(0.30R_{DTW})]]+ [7[(0.83R_{WCL})+(0.17R_{CON})]]]/17$.....(5)

Where $LAFI_{ENV}$= Landscape agroforestry indices in term of environmental factor

R_{SOT} = ranking of soil types

R_{SLP} = ranking of slope

R_{DTW} = ranking of distance to water

R_{WCL} = ranking of watershed classes

R_{CON} = ranking of conservation area

3. Agroforestry index in term of environmental factor

Sample plots were observed in each indicator of AFI, in these results were shown in Table 8. Seven in eleven land use types were observed in organic matter, soil erosion and species diversity in Huai Raeng-Klong Peed sub-watershed.

Department of Land Development determined the levels of organic matter affect to plantation. The results were compared with the

Table 4 Weighted value of agroforestry indices in each indicator for sufficiency economy

Environment = 10 (Consistency ratio, CR = 0.066)	Weighted Value	Economy = 8 (Consistency ratio, CR = 0.066)	Weighted Value
Soil properties	0.10	Income distribution	0.30
Soil erosion	0.69	Net farm income	0.09
Vegetation	0.21	Resources using	0.61
Indicators of soil properties (Consistency ratio, CR = 0.066)		Social = 10 (Consistency ratio, CR = 0)	Weighted Value
Organic matter	0.69	Land holding side	0.17
Bulk density	0.10	Acceptation of land use	0.83
Soil moisture	0.21		
Indicators of vegetation (Consistency ratio, CR = 0.078)			
Percentage of crown cover	0.06		
Stratification of crown cover	0.15		
Biomass	0.22		
Species diversity	0.57		

Table 5 Weighted value of landscape agroforestry indices in each indicator for sufficiency economy

Environment = 10 (Consistency ratio, CR = 0066)	Weighted Value	Institutions related = 7 (Consistency ratio, CR = 0.066)	Weighted Value
Soil properties(soil types)	0.09	Watershed classes	0.83
Topography(slope)	0.61	Conservation area	0.17
Water resources(distance to water)	0.30		
Social = 10 (Access to main road)			

Table 6 Agroforestry index classes

Agroforestry index classes (AFIC)	Agroforestry indices (AFI)	Sufficiency economy level (SE Level)
1	4.2-5.0	Highest
2	3.4-4.2	High
3	2.6-3.4	Medium
4	1.8-2.6	Low
5	1.0-1.8	Lowest

Table 7 Landscape agroforestry index classes

Landscape Agroforestry indices classes (LAFIC)	Landscape Agroforestry indices (LAFI)	Suitable Index level (SI level)
1	4.2-5.0	Highest
2	3.4-4.2	High

3	2.6-3.4	Medium
4	1.8-2.6	Low
5	1.0-1.8	Lowest

Table 8 The results of sample plots in each of land use types in environmental factor

No.LU	Land use types	Organic matter (%)	Soil erosion (tons/ha/y)	Species diversity	
				Number of Species	Diversity index Shannon index (H')
1	Oil Palm	1.78	2.67[2]	1	0
2	Rubber plantation/fruit orchard	2.31	0.62[1]	2	0.655
3	Rubber plantation	2.41	0.97[1]	1	0
4	Mixed fruit orchard	2.74	1.66[1]	2	0.693
5	Eagle Wood /Para rubber	3.32	1.60[1]	2	0.691
6	Residential and Mixed fruit	2.05	0.38[1]	6	1.505

Source: [1]Khangsap (2004) and [2]Hashima *et al.* (2008)

determination. Oil palm, Residential and Mixed fruit, Rubber plantation/fruit orchard and Rubber plantation have organic matter in 1.5-2.5% that is moderate level. The others have high moderate level. Only oil palm has lower than 2.0% that should improve the soil. The eagle wood /para rubber was highest organic matter. Mixes fruit orchard were 3.32 and 2.74%, respectively. This conclusion supports the criticism of Yeoh *et al* (2011), which argued organic matter content at the 0 to 15 cm depth of forest; cropland and grassland were estimated at 2.27, 2.07 and 0.83%, respectively.

Soil erosion value were found in oil palm that highest as 2.67 (ton/ha/y). Mixes fruit orchard, eagle wood/para rubber, rubber plantation, rubber plantation/fruit orchard and residential and mixes fruit were found soil erosion value 1.66, 1.60, 0.97 and 0.38(tons/ha/y), respectively. Soil erosion is a complex process that depends on soil properties, ground slope, vegetation, and rainfall amount and intensity (Selby, 1993). Changing in land use are widely recognized as capable of greatly accelerated soil erosion (Ursic *et al.*, 1965), Difference variety environment authors agree that runoff and sediment yield decrease with an increase in soil cover with vegetation (Duran *et al.*, 2006; Francis *et al.*, 1990). Therefore, these results of soil erosion in each land use type conformed this argued in case of oil palm has the highest soil erosion value because it has plant cover 0.18 plant/m^2 and mixes fruit orchard 0.29 plant/m^2.

The species diversity studied in diversity, the residential and mixed fruit has diversity index highest than others land use types. Mixed fruit orchard, Eagle wood /Para rubber and rubber plantation/fruit orchard were 0.763, 0.693, 0.61 and 0.655, respectively. The species diversity index of

oil palm and rubber plantation have the lowest level of diversity index that mean monocropping reduce biodiversity. These findings are in agreement with other observations on (Brookfield, 2001; Thrupp, 1998; Rajendra *et al*, 2010).

The results of AFI indices after sampling plot were rank as 5 intervals are equal that was shown in Table 9. Then the results of AFI indices after sampling plot were considered as representative ranking score. After that they were taken into the agroforestry index equation (3) in term of environment factor. The total these are agroforestry index in term of environment factor, as shown in Table 10. All of these results were found; the residential and mixed fruit, rubber plantation/fruit orchard, eagle wood/rubber plantation, para rubber plantation and mixed fruit orchard were 46, 42.8, 36.9, 32.7 and 30, respectively. The oil palm was lowest weighed value of environment as 10.

4. Landscape agroforestry index in term of environmental factor

Landscape agroforestry is defined as the concept of land suitability of FAO. According to the FAO methodology (1976), this is strongly related to the land qualities. The suitability order defines and is expressed as following in Table 11.

4.1 Ranking score of indicator

4.1.1 Soil types

Soil types are difference characteristics, which consists of surface characteristics, organic matter, bulk density, soil color, soil pH and so on. Soil texture is one important characteristic of soil types. Soil texture can determination the rate of water drain, and also influences available of water to the plant. In addition, well drained soils typically have good soil aeration meaning that the soil contains air that is similar to atmospheric air, which is conducive to healthy root growth, and thus a healthy crop. Differences in soil texture also impacts organic matter levels. The cation exchange capacity of the soil increases with percent clay and organic matter and the pH buffering capacity of a soil, is also largely based on clay and organic matter content (Berry *et al*, 2007). Plante *et al*. (2006) examine how soil texture differentially alters the distribution of organic carbon within physically and chemically defined pools of unprotected and protected soil organic matter. They found whole-soil organic carbon concentration was positively related to silt plus clay content at both sites. The United States Department of Agriculture: USDA (1987) has divided soil type classes as five levels. The ranking score is following in Table 12.

Table 9 Interval classes of environmental indices and ranking score

Ranking score	Interval classes		
	organic matter	soil erosion	diversity index
5	> 3.012	0.381-0.839	>1.233
4	2.705-3.012	0.840-1.297	0.925-1.232
3	2.397-2.704	1.298-1.756	0.617-0.924
2	2.089-2.396	1.757-2.214	0.309-0.616
1	1.78-2.088	>2.214	0-0.308

Table 10 Sufficiency economy level in term of environmental factor

Land use No.	organic matter		soil erosion		species diversity		AFI	AFIC	SE Level
	Ranking score	Weighed value (0.10)	Ranking score	Weighed value (0.69)	Ranking score	Weighed value (0.21)			
1	1	0.1	1	0.69	1	0.2	1.0	5	Lowest
2	2	0.2	5	3.45	3	0.6	4.3	1	Highest
3	3	0.3	4	2.76	1	0.2	3.3	3	Medium
4	3	0.3	3	2.07	3	0.6	3.0	3	Medium
5	5	0.5	3	2.07	3	0.6	3.2	3	Medium
6	1	0.1	5	3.45	5	1.1	4.6	1	Highest

Table 11 Land suitability classes

Order	Class	Description	Ranking
Suitable	S1 (Highly suitable)	Land having no, or insignificant limitations to the given type of use	5
	S2 (Moderately suitable)	Land having minor limitations to the given type of use	4
	S3 (Marginally suitable)	Land having moderate limitations to the given type of use	3
Not suitable	N1 (Currently not suitable)	Land having severe limitations that preclude the given type of use, but can be improved by specific management	2
	N2 (Permanently not suitable)	Land that have so severe limitations that are very difficult to be overcome	1

Source : FAO (1976)

Table 12 soil textural classification and ranking

Texture	%clay	Soil types	Ranking score
Very coarse	<10%	Sand	1
Coarse		Loamy sand	
Moderately coarse	10-20%	Sandy loam	2
Medium	20%	Loam	3
		Silt loam	
		Silt	
Moderate fine	20-30%	Sandy clay loam	4
		Sandy clay	
		Silt clay	
		Clay	
Fine	>30%	Heavy clay >60% clay	5

Source : USDA (1987)

4.1.2 Slope

The slope classes are studied in area of slope classes for cultivation and studied from the relevant literature. Koulouri *et al.* (2007) studied in land abandonment and slope gradient as key factor of soil erosion. This research concluded the slope gradient is steep (25%), soil erosion is increasing significantly. In addition, FAO (1990) said, the slope < 7° is flat to gently sloping. It is a broad base terraces or other simple conservation treatments can be used up to 7°. Therefore slope 1-6% is suitability for cultivation but slope > 25% is unsuitability for cultivation. Moreover the relevant literature in area of land suitability for cultivation are defined as the same in watershed classification in Thailand (Bunruamkaew *et al.,* 2011; Ochola *et al.,* 2004), which divided into 5 level as following in Table 13.

4.1.3 Distance to water

The USDA studied in the riparian forest buffer that concluded the streamside forest can function as a sink when nutrients are taken up by plants and sequestered in plant tissue. The streamside forest is assimilated in tree growth which may be stored for extended periods of time in woody tissue and possibly removed as logs or other forest products. The land after 95 ft or 28.95 meter from a river is a carefully managed for sediment, fertilizer and pesticides (Welsch , n.d.). Van Koppen *et al*. (2009) study in understand how and how much water is involved in domestic and productive activities. The results show; the distance <50 meter is suitability for vegetable, < 200 meter is suitable for fruit trees and 250 meter – 1 kilometer is not suitable for productive uses. From above that can divide and rank score into 5 levels as following in Table 14.

4.1.4 Watershed classes

Watershed classes is divided into 5 zones with the first (WSC1) and the second (WSC2) are preserved as protection and commercial forests respectively and the rests (WSC3-WSC5) belong to agricultural and other purposes with appropriate conservation (Tangtham, 1996). From above that can divide and rank score into 5 levels as following in Table 15.

Table 13 slope classification and ranking

Slope classes	Characteristics	Ranking score
>60%	Very steep	1
35-50%	Steep	2
25-35%	Gentle	3
6-25%	Very gentle	4
<6%	Flat	5

Table 14 distance to water

Distance to water	Description	Ranking score
<30 meter	Protected area for ecosystem	1
30-50 meter	Suitability area for vegetable	5

50-200 meter	Suitability area for fruit trees.	4
>200 meter	Suitability area for cultivation in rain-fed	2

Table 15 watershed classes

Watershed classes	Detail	Ranking score
WSC 1A,1B	Protected or Conservation forest and headwater source.	1
WSC 2	Commercial forest: These areas are designed for protection and/or commercial forests where mining and logging will be allowed within legal boundaries.	2
WSC 3	Fruit-tree plantation: These areas cover uplands with steep slopes and less erosive landforms. Areas may be used for commercial forests, grazing, fruit trees, or certain agricultural crops with need for soil conservation measures.	3
WSC 4	Upland farming: This class describes those areas of gentle sloping lands suitable for row crops, fruit trees, and grazing with a moderate need for few soil conservation measures.	4
WSC 5	Lowland farming: WSC 5 are gentle slopes or flat areas needed for paddy fields or other agricultural uses with few restrictions.	5

Source : Tangtham(1996)

4.1.5 Protected area

The legal authority for Thailand's protected areas is the Wild Animals Reservation and Protection Act (WARPA) of 1960 and the National Park Act of 1961 (Arbhabhirama *et al*., 1988; Dixon *et al.*, 1990; Gray *et al*., 1994). There are four main types of protected areas in Thailand: national park, wildlife sanctuary, non hunting area, and forest park. Other kinds of protected areas include botanical gardens, which are reserved for collecting and planting native and exotic rare and economically valuable plant species (Arbhabhirama *et al*., 1988; Panusittikorn, 2001). The national park is one of conservation area that has affected in the study area. Thus the area in national park has ranking score is 5 and the other area has ranking score is 1.

The ranking score from above were established landscape agroforestry map each indicator as following in Figure 3.

4.1.6 Landscape agroforestry index class map in term of environmental factor

The landscape agroforestry index class map in term of environmental factor ($LAFIC_{ENV}$ map) was taken into the landscape agroforestry equation (5) in term of environmental factor. Map algebra in ArcGIS is tool to establish the landscape agroforestry class map. It was shown in Figure 4. The $LAFIC_{ENV}$ map which is follow in the equation or is unremarkable as shown in Figure 4 A. In addition, the existing forest area is important to protect for ecosystem. Therefore the existing forest area is considered in the $LAFIC_{ENV}$ map as shown in Figure 4

The $LAFIC_{ENV}$ map which is follow the equation or is unremarkable was found landscape agroforestry 5 levels. The highest suitable area has 125.52 km^2, high suitable area has 233.99 km^2, medium suitable area has 61.01 km^2, low suitable area has 23.30 km^2 and the lowest suitable area has 3.75 km^2.

The $LAFIC_{ENV}$ map which is immovable forest area was found landscape agroforestry classes 5 levels. The highest suitable area has 113.61 km^2, high suitable area has 172.47 km^2, medium suitable area has 3.02 km^2, low suitable has 0.01 km^2 and the lowest suitable area has 158.10 km^2.B**.**

CONCLUSION AND RECOMMENDATION

The goal of this research is landscape agroforestry for sufficiency economy. The investigation was what the indicators to indicate land use type appropriate for sufficiency economy is and what the indicators to indicate land quality to for land use is. The relevant literatures were assessed a key performance to indicate the agroforestry under sufficiency economy. There are three factors consist of environment, economy and social. The agroforestry indices (AFI); in environment factor consists three criteria as soil properties (organic matter), soil erosion and vegetation (species diversity). The landscape agroforestry indices (LAFI); in environment factor is soil properties (soil types) and in institutions related factor is land use policy (watershed class and conservation area).

Those factor and indicator were estimated weighting by experts on mailed questionnaire. The results were calculated using AHP technique. Weighing was taken into linear equation that is landscape agroforestry modeling through to sufficiency economy in term of environmental factor; there are agroforestry index equation to investigate land use type that appropriate to sufficiency economy in term of environmental factor, and landscape agroforestry index equation to investigate land quality for land use under

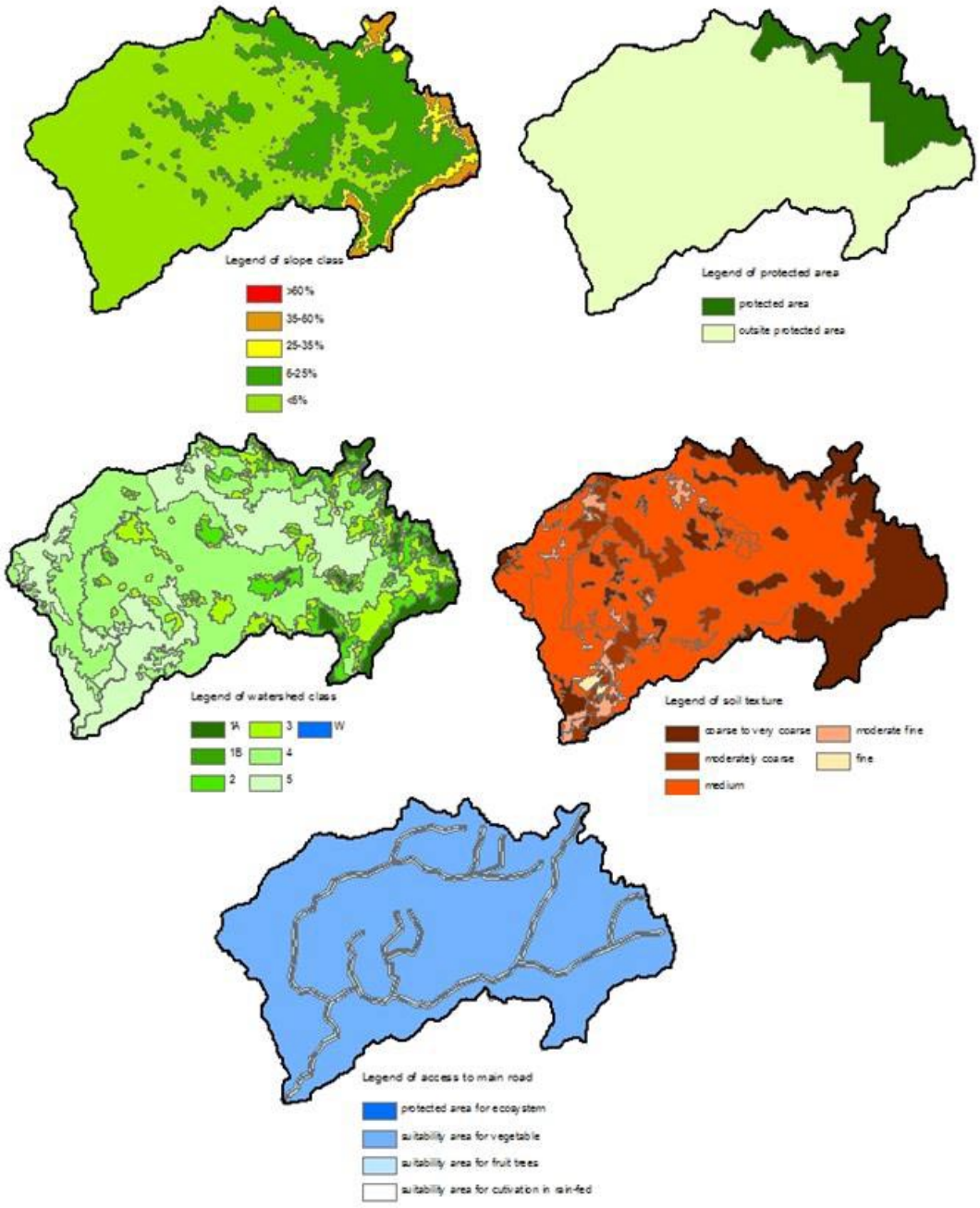
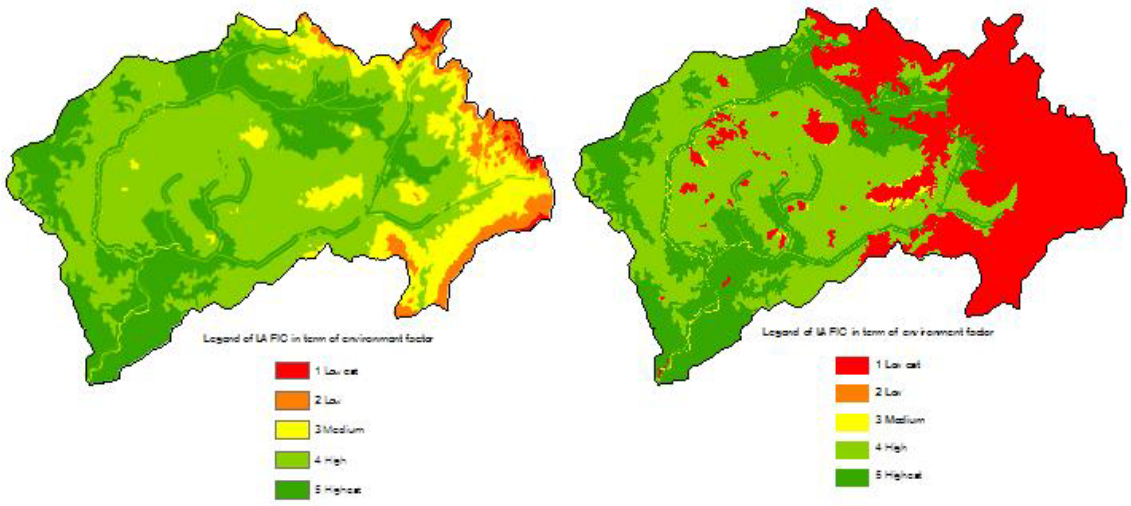


Figure 3 Landscape agroforesty map each indicator



A: LAFIC map in term of environmental factor which is unremarkable

B: LAFIC map in term of environmental factor which is immovable forest area

Figure 4 Landscape agroforesty index class map in term of environmental factor

sufficiency economy in term of environmental factor.

The agroforestry indices in term of environmental factor were measured in sampling plot in organic matter, soil erosion and species diversity in Huai Raeng-Klong Peed sub-watershed. The results showed the effect of land use after production. All of these results show sufficiency economy level in term of environment, residential and mixed fruit, and rubber plantation/fruit orchard were the highest level, the medium level were rubber plantation, mixes fruit orchard and eagle wood /para rubber. The lowest level was oil palm.

The landscape agroforestry index class map in term of environmental factor ($LAFIC_{ENV}$ map) was taken into the landscape agroforestry equation in term of environmental factor. The comparison between the map of unremarkable or follow the equation and the map which is immovable forest. The distinct lowest suitable area was 3.75 km^2 to 158.10 km^2, respectively. While each level of area was slightly. The highest area in unremarkable condition was high suitable area as 233.99 km^2 but the highest area in immovable condition was high suitable area as 172.47 km^2. The both conditions still have the highest and high area for cultivation more than half of total area.

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